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(54) Title: ANTIREFLECTIVE SIO-CONTAINING COMPOSITIONS FOR HARDMASK LAYER

(57) Abstract: Antireflective compositions characterized by the presence of an SiO-containing polymer having chromophore moi-  
eties and transparent moieties are useful antireflective hardmask compositions in lithographic processes. These compositions provide  
outstanding optical, mechanical and etch selectivity properties while being applicable using spin-on application techniques. The com-  
positions of the invention are advantageously useful with shorter wavelength lithographic processes and/or have minimal residual acid  
content.

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## Antireflective SiO-Containing Compositions For Hardmask Layer

### Background of the Invention

In the microelectronics industry as well as in other industries involving construction of microscopic structures (e.g. micromachines, magnetoresistive  
5 heads, etc.), there is a continued desire to reduce the size of structural features. In the microelectronics industry, the desire is to reduce the size of microelectronic devices and/or to provide greater amount of circuitry for a given chip size.

Effective lithographic techniques are essential to achieving reduction of  
10 feature sizes. Lithography impacts the manufacture of microscopic structures not only in terms of directly imaging patterns on the desired substrate, but also in terms of making masks typically used in such imaging. Typical lithographic processes involve formation of a patterned resist layer by patternwise exposing the radiation-sensitive resist to an imaging radiation.  
15 The image is subsequently developed by contacting the exposed resist layer with a material (typically an aqueous alkaline developer) to selectively remove portions of the resist layer to reveal the desired pattern. The pattern is subsequently transferred to an underlying material by etching the material in openings of the patterned resist layer. After the transfer is complete, the  
20 remaining resist layer is then removed.

For some lithographic imaging processes, the resist used does not provide sufficient resistance to subsequent etching steps to enable effective transfer of the desired pattern to a layer underlying the resist. In many instances (e.g., where an ultrathin resist layer is desired, where the underlying  
25 material to be etched is thick, where a substantial etching depth is required, and/or where it is desired to use certain etchants for a given underlying material), a so-called hardmask layer is used intermediate between the resist layer and the underlying material to be patterned by transfer from the patterned resist. The hardmask layer receives the pattern from the patterned

resist layer and should be able withstand the etching processes needed to transfer the pattern to the underlying material.

While many hardmask materials exist in the prior art, there is a continued desire for improved hardmask compositions. Many of the prior art materials are difficult to apply to the substrate, e.g., they may require use of chemical or physical vapor deposition, special solvents, and/or high temperature baking. It would be desirable to have hardmask compositions which could be applied by spin-coating techniques without need for a high temperature bake. Additionally, it is desirable to have hardmask compositions which can be easily etched selective to the overlying photoresist while being resistant to the etch process needed to pattern the underlying layer, especially where the underlying layer is a metal layer. It is also desired to provide adequate shelf-life and to avoid adverse interaction with the imaging resist layer (e.g., by acid contamination from the hardmask). Additionally, it is desired to have hardmask compositions which possess the desired optical characteristics relative to shorter wavelength (e.g., < 200 nm) imaging radiation.

#### Summary of the Invention

The invention encompasses novel antireflective hardmask compositions which are useful in lithographic processes. These compositions provide outstanding optical, mechanical and etch selectivity properties while being applicable using spin-on application techniques. The compositions also have good shelf-life and minimal or no acid contaminant content. The antireflective hardmask compositions are characterized by the presence of an SiO-containing polymer having chromophore moieties and transparent moieties. The invention also encompasses methods of using the hardmask compositions of the invention to pattern underlying material layers on a substrate. The invention also encompasses lithographic structures such as a patterned combination of resist layer and hardmask layer.

In one aspect, the invention encompasses a composition suitable for formation of a spin-on antireflective hardmask layer, the composition comprising:

- 5 (a) an SiO-containing polymer having chromophore moieties and transparent moieties,
- (b) a crosslinking component, and
- (c) an acid generator.

The SiO moieties are preferably selected from the group consisting of siloxane moieties and silsesquioxane moieties. The SiO moieties are preferably in a backbone portion of the polymer. The SiO-containing polymer  
10 also preferably contains a plurality of reactive sites distributed along the polymer for reaction with the crosslinking component. The acid generator is preferably a thermally activated acid generator. The transparent moieties are preferably bulky (C<sub>2</sub> or higher) or fluorine-containing moieties which are  
15 substantially transparent to the desired imaging radiation.

In another aspect, the invention encompasses method of forming a patterned material feature on a substrate, the method comprising:

- (a) providing a material layer on a substrate,
- 20 (b) forming an antireflective hardmask layer of the invention over the material layer,
- (c) forming a radiation-sensitive imaging layer over the antireflective layer,
- (d) patternwise exposing the imaging layer to radiation thereby creating a pattern of radiation-exposed regions in the imaging  
25 layer,
- (e) selectively removing portions of the imaging layer and the antireflective layer to expose portions of the material layer, and
- (f) etching the exposed portions of the material layer, thereby forming the patterned material feature.

The material to be patterned is preferably a conductive, semiconductive, magnetic or insulative material, more preferably a metal. The SiO moieties are preferably in a backbone portion of the polymer. The SiO-containing polymer also preferably contains a plurality of reactive sites distributed along  
5 the polymer for reaction with the crosslinking component.

These and other aspects of the invention are discussed in further detail below.

#### Detailed Description of the Invention

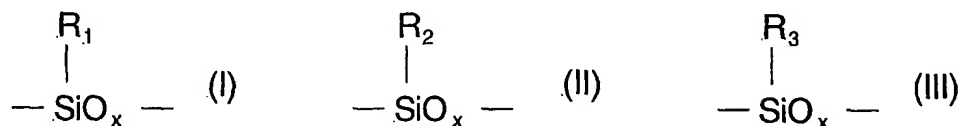
The invention encompasses novel antireflective hardmask  
10 compositions which are useful in lithographic processes. These antireflective hardmask compositions are characterized by the presence of an SiO-containing polymer having chromophore moieties and transparent moieties. The invention also encompasses methods of using the antireflective hardmask compositions of the invention to pattern underlying  
15 material layers on a substrate. The invention also encompasses lithographic structures such as a patterned combination of resist layer and hardmask layer.

The antireflective hardmask compositions of the invention generally comprise:

- 20 (a) an SiO-containing polymer having chromophore moieties and transparent moieties,
- (b) a crosslinking component, and
- (c) an acid generator.

The SiO-containing polymer preferably contains SiO moieties in its  
25 backbone. The polymer is preferably an organosiloxane, more preferably organosilsesquioxane. The polymer should have solution and film-forming characteristics conducive to forming a layer by conventional spin-coating.

In general, the polymer preferably contains one or more monomers having structures selected from (I) - (III) below:



where x is from about 1 to about 1.5. R<sub>1</sub> comprises a chromophore moiety;  
 5 R<sub>2</sub> comprises a transparent moiety; R<sub>3</sub> comprises a reactive site for reaction with the crosslinking component. For linear organosiloxane polymers, x would equal about 1. For silsesquioxane polymers, x would equal about 1.5. In some instances, multiple functional moieties may be present on the same monomer (e.g., a reactive group and a chromophore). Generally,  
 10 silsesquioxane polymers are preferred on the basis of superior etch resistance. If the ordinary organosiloxane polymers are used, then preferably, the degree of crosslinking is increased compared to formulations based on silsesquioxanes.

The chromophore-containing groups R<sub>1</sub> may contain any suitable  
 15 chromophore which (i) can be grafted onto the SiO-containing polymer (ii) has suitable radiation absorption characteristics, and (iii) does not adversely affect the performance of the layer or any overlying photoresist layers. Preferred chromophore moieties include phenyl, chrysenes, pyrenes, fluoranthrenes, anthrones, benzophenones, thioxanthenes, and anthracenes. Anthracene  
 20 derivatives, such as those described in U.S. Patent 4,371,605 may also be used; the disclosure of this patent is incorporated herein by reference. 9-anthracene methanol is a preferred chromophore. The chromophore moiety preferably does not contain nitrogen, except for possibly deactivated amino nitrogen such as in phenol thiazine. For 193nm radiation,  
 25 non-aromatic compounds containing unsaturated carbon bonds (e.g., carbon-carbon double bonds) are also suitable chromophores. For 157nm radiation, compounds containing saturated carbon-carbon bonds can act as chromophores.

The chromophore moieties may be chemically attached to the SiO containing polymer by acid-catalyzed O-alkylation or C-alkylation such as by Friedel-Crafts alkylation. Alternatively, the chromophore moiety may be attached by an esterification mechanism. A preferred acid for Friedel-Crafts catalysis is HCl. Preferably, about 15 to 40% of the monomers contain chromophore moieties. In some instances, it may be possible to bond the chromophore to the monomer before formation of the SiO-containing polymer, however this is generally not preferred. The site for attachment of the chromophore is preferably an aromatic group such as a hydroxybenzyl or hydroxymethylbenzyl group. Alternatively, the chromophore may be attached by reaction with other moieties such as cyclohexanol or other alcohols. The reaction to attach the chromophore is preferably an esterification of the alcoholic OH group.

R<sub>2</sub> transparent moieties may vary depending on the wavelength or character of the imaging radiation. In the case of 193 nm imaging radiation, the transparent moieties are preferably a bulky (C<sub>2</sub> or higher) organic moieties substantially free of unsaturated carbon-carbon bonds. A preferred transparent moiety for 193 nm applications is an alcohol derived from an epoxy-functionalized silsesquioxane monomer. In the case of 157 nm imaging radiation, the transparent moieties are preferably fluorine-containing moieties such as a trifluoromethyl group or perfluoroalkyl. The amount of transparent moieties is preferably balanced with the amount of chromophore to provide a desired combination of energy absorption and antireflection.

R<sub>3</sub> comprises a reactive site for reaction with the crosslinking component. Preferred reactive moieties contained in R<sub>2</sub> are alcohols, more preferably aromatic alcohols (e.g., hydroxybenzyl, phenol, hydroxymethylbenzyl, etc.) or cycloaliphatic alcohols (e.g., cyclohexanoyl). Alternatively, non-cyclic alcohols such as fluorocarbon alcohols, aliphatic alcohols, amino groups, vinyl ethers, and epoxides may be used.

Examples of SiO containing polymers include:

poly(3-propanoloxypropyl)silsesquioxane, copolymer of  
3-propanoloxypropylsilsesquioxane and phenylsilsesquioxane, blend of  
poly(hydroxybenzyl)silsesquioxane and poly(1-hydroxy-1-trifluoromethylethyl)  
5 silsesquioxane, copolymer of 1-hydroxy-1-trifluoromethylethylsilsesquioxane  
and p-Hydroxymethylbenzylsilsesquioxane.

The SiO-containing polymers of the invention preferably have a weight  
average molecular weight, before reaction with the crosslinking component, of  
at least about 1000, more preferably a weight average molecular weight of  
10 about 1000-10000.

The crosslinking component is preferably a crosslinker that can be  
reacted with the SiO-containing polymer in a manner which is catalyzed by  
generated acid and/or by heating. Generally, the crosslinking component  
used in the antireflective hardmask compositions of the invention may be any  
15 suitable crosslinking agent known in the negative photoresist art which is  
otherwise compatible with the other selected components of the composition.  
The crosslinking agents preferably act to crosslink the polymer component in  
the presence of a generated acid. Preferred crosslinking agents are glycoluril  
compounds such as tetramethoxymethyl glycoluril,  
20 methylpropyltetramethoxymethyl glycoluril, and  
methylphenyltetramethoxymethyl glycoluril, available under the  
POWDERLINK trademark from Cytac Industries. Other possible crosslinking  
agents include: 2,6-bis(hydroxymethyl)-p-cresol  
compounds such as those found in Japanese Laid-Open Patent Application  
25 (Kokai) No. 1-293339, etherified amino resins, for example methylated or  
butylated melamine resins (N-methoxymethyl- or N-butoxymethyl- melamine  
respectively), and methylated/butylated glycolurils, for example as can be  
found in Canadian Patent No. 1 204 547. Other crosslinking agents such as

bis-epoxies or bis-phenols (e.g., bisphenol-A) may also be used.  
Combinations of crosslinking agents may be used.

The acid generator is preferably an acid generator compound is employed that liberates acid upon thermal treatment. A variety of known  
5 thermal acid generators are suitably employed such as e.g. 2,4,4,6-tetrabromocyclohexadienone, benzoin tosylate, 2-nitrobenzyl tosylate and other alkyl esters of organic sulfonic acids. Compounds that generate a sulfonic acid upon activation are generally suitable. Other suitable thermally activated acid generators are described in US Patents 5,886,102 and  
10 5,939,236; the disclosures of these two patents are incorporated herein by reference. If desired, a radiation-sensitive acid generator may be employed as an alternative to a thermally activated acid generator or in combination with a thermally activated acid generator. Examples of suitable radiation-sensitive acid generators are described in US Patents 5,886,102  
15 and 5,939,236. Other radiation-sensitive acid generators known in the resist art may also be used as long as they are compatible with the other components of the antireflective composition. Where a radiation-sensitive acid generator is used, the cure (crosslinking) temperature of the composition may be reduced by application of appropriate radiation to induce acid  
20 generation which in turn catalyzes the crosslinking reaction. Even if a radiation-sensitive acid generator is used, it is preferred to thermally treat the composition to accelerate the crosslinking process (e.g., for wafers in a production line).

The antireflective hardmask compositions of the invention preferably  
25 contain (on a solids basis) (i) about 50-98 wt.% of the SiO-containing polymer, more preferably about 70-80 wt.%, (ii) about 1-50 wt.% of crosslinking component, more preferably about 3-25%, and (iii) about 1-20 wt.% acid generator, more preferably about 1-15 wt.%.

The antireflective hardmask compositions of the invention may be used in combination with any desired resist material in the forming of a lithographic structure. Preferably, the resist is imageable with shorter wavelength ultraviolet radiation (e.g. < 200 nm wavelength) or with electron beam radiation. Examples of suitable resist materials are described in US Patent 6,037,097, the disclosure of which is incorporated herein by reference.

The antireflective hardmask compositions of the invention will typically contain a solvent prior to their application to the desired substrate. The solvent may be any solvent conventionally used with resists which otherwise does not have any excessively adverse impact on the performance of the antireflective composition. Preferred solvents are propylene glycol monomethyl ether acetate, cyclohexanone, and ethyl lactate. The amount of solvent in the composition for application to a substrate is preferably sufficient to achieve a solids content of about 8-20 wt.%. Higher solids content formulations will generally yield thicker coating layers. The compositions of the invention may further contain minor amounts of auxiliary components (e.g., base additives, etc.) as may be known in the art.

The antireflective hardmask compositions of the invention can be prepared by combining the polymer, crosslinking component and acid generator, and any other desired ingredients using conventional methods. The compositions of the invention advantageously may be formed into antireflective hardmask layers on a substrate by spin-coating followed by baking to achieve crosslinking and solvent removal. The baking is preferably conducted at about 250°C or less, more preferably about 150°-220°C. The baking time may be varied depending on the layer thickness and bake temperature.

The thickness of the antireflective hardmask composition of the invention may be varied depending on the desired function. For typical applications, the thickness of the composition is preferably about 0.02 - 5.0

$\mu\text{m}$ , more preferably about 0.1 - 5.0  $\mu\text{m}$ . If desired, the compositions of the invention may also be used as dielectric materials in a similar manner to conventional spin-on glass materials. The compositions of the invention advantageously resist lateral etch such that they may act as hard masks even  
5 at thin film thickness traditionally associated with organic antireflective layers.

The hardmask compositions of the invention are especially useful for lithographic processes used in the manufacture of integrated circuits on semiconductor substrates. The compositions are especially useful for lithographic processes using 193 nm, 157 nm, EUV, x-ray, e-beam or other  
10 imaging radiation.

Semiconductor lithographic applications generally involve transfer of a pattern to a layer of material on the semiconductor substrate. The material layer of the semiconductor substrate may be a metal conductor layer, a ceramic insulator layer, a semiconductor layer or other material depending on  
15 the stage of the manufacture process and the desired material set for the end product. The composition of the invention is preferably applied directly over the material layer to be patterned, preferably by spin-coating. The composition is then baked to remove solvent and cure (crosslink) the composition. A radiation-sensitive resist layer can then be applied (directly or  
20 indirectly) over the cured antireflective composition of the invention.

Typically, the solvent-containing resist composition is applied using spin coating or other technique. The substrate with the resist coating is then preferably heated (pre-exposure baked) to remove the solvent and improve the coherence of the resist layer. The thickness of the applied layer is  
25 preferably as thin as possible with the provisos that the thickness is preferably substantially uniform and that the resist layer be sufficient to withstand subsequent processing (typically reactive ion etching) to transfer the lithographic pattern to the underlying substrate material layer. The pre-exposure bake step is preferably conducted for about 10 seconds to 15

minutes, more preferably about 15 seconds to one minute. The pre-exposure bake temperature may vary depending on the glass transition temperature of the photoresist.

After solvent removal, the resist layer is then patternwise-exposed to the desired radiation (e.g. 193 nm ultraviolet radiation). Where scanning particle beams such as electron beam are used, patternwise exposure may be achieved by scanning the beam across the substrate and selectively applying the beam in the desired pattern. More typically, where wavelike radiation forms such as 193 nm ultraviolet radiation, the patternwise exposure is conducted through a mask which is placed over the resist layer. For 193 nm UV radiation, the total exposure energy is preferably about 100 millijoules/cm<sup>2</sup> or less, more preferably about 50 millijoules/cm<sup>2</sup> or less (e.g. 15-30 millijoules/cm<sup>2</sup>).

After the desired patternwise exposure, the resist layer is typically baked to further complete the acid-catalyzed reaction and to enhance the contrast of the exposed pattern. The post-exposure bake is preferably conducted at about 60-175°C, more preferably about 90-160°C. The post-exposure bake is preferably conducted for about 30 seconds to 5 minutes.

After post-exposure bake, the resist structure with the desired pattern is obtained (developed) by contacting the resist layer with an alkaline solution which selectively dissolves the areas of the resist which were exposed to radiation. Preferred alkaline solutions (developers) are aqueous solutions of tetramethyl ammonium hydroxide. The resulting lithographic structure on the substrate is then typically dried to remove any remaining developer solvent.

The pattern from the resist structure may then be transferred to the exposed portions of the layer of antireflective material of the invention by etching with CF<sub>4</sub> or other suitable etchant using techniques known in the art.

After the opening of the layer of antireflective hardmask of the invention, the underlying material layer to be patterned may then be etched using an etchant appropriate to the material layer composition. Where the material layer is a metal (e.g., Cr) a combination of  $\text{Cl}_2/\text{O}_2$  may be used as a  
5 dry etchant.

Once the desired pattern transfer has taken place, any remaining resist may be removed using conventional stripping techniques. If the composition of the invention is being used strictly as a hardmask, the composition of the invention may be removed by contacting with a  $\text{CF}_4/\text{O}_2$  plasma.

10 Thus, the compositions of the invention and resulting lithographic structures can be used to create patterned material layer structures such as metal wiring lines, holes for contacts or vias, insulation sections (e.g., damascene trenches or shallow trench isolation), trenches for capacitor structures, etc. as might be used in the design of integrated circuit devices.  
15 The compositions are especially useful in the context of creating patterned layers of oxides, nitrides or polysilicon.

Examples of general lithographic processes where the composition of the invention may be useful are disclosed in US Patents 4,855,017; 5,362,663; 5,429,710; 5,562,801; 5,618,751; 5,744,376; 5,801,094;  
20 5,821,469 and 5,948,570, the disclosures of which patents are incorporated herein by reference. Other examples of pattern transfer processes are described in Chapters 12 and 13 of "Semiconductor Lithography, Principles, Practices, and Materials" by Wayne Moreau, Plenum Press, (1988), the disclosure of which is incorporated herein by reference. It should be  
25 understood that the invention is not limited to any specific lithographic technique or device structure.

## Example 1

## (Polymer A)

The silicone precursor 3-glycidoxypropyltrimethoxysilane (47.26 g, 200 mmol) (available from Aldrich) was dissolved in 100 ml of tetrahydrofuran (THF) and then hydrolyzed by a mixture of THF and 1 N HCl at room temperature. The reaction mixture was then refluxed for 18 hours to complete the hydrolysis. After cooling down to room temperature, 150 ml of diethylether were added and the aqueous phase was separated from the organic phase and discarded. The organic phase was washed with brine (50 ml) twice and dried over magnesium sulfate, followed by removal of the solvent in vacuum, leaving the polymer as a clear viscous oil behind. The polymer was dried in vacuum and the final yield was ca. 27 g. The material was characterized by NMR and IR, showing that the epoxy functional group was converted to an alcohol functional group.

## 15 (Polymer B)

The silicone precursors phenyltrimethoxysilane (7.92 g, 40 mmol) and 3-glycidoxypropyltrimethoxysilane (37.82 g, 160 mmol) ( both available from Aldrich) were reacted in the same manner described in for Polymer A to give the polymer in a final yield of ca. 25 g.

## 20 (Polymer C)

Poly(hydroxybenzyl)silsesquioxane (PHBSQ - obtained from DayChem Laboratories in Vandalia, Ohio)

## (Polymer D)

Poly(1-Hydroxy-1-Trifluoromethylethyl) silsesquioxane (TFASSQ) was synthesized according to the procedure of U.S. Patent Application Ser. No. 09/748071 ("Substantially Transparent Aqueous Base Soluble Polymer System For Use In 157 nm Resist Applications") filed December 21, 2000.

## Example 2

## Formulation

The desired SiO-containing polymer component was dissolved in propylene glycol monomethyl ether acetate (PGMEA) in concentrations of 100 parts by weight. A crosslinking agent tetramethoxymethyl glycoluril, available from DayChem, in a concentration of 8 parts by weight and di(t-butylphenyl)iodoniumperfluorobutylsulfonate (DtBPI-PFBuS) in a concentration of 4 parts by weight were added to the solution, achieving 14 wt.% of total solids.

## 10 Example 3

## Film formation and optical properties

Formulations, prepared as described in Example 2, were spin coated onto a 300 mm silicon wafer at 3000 rpm for 60 sec. The film thickness was about 2500 Å. The spin cast film was cured at 200°C for 60 sec. The optical constants (the index of refraction  $n$  and the extinction coefficient  $k$  at 193 nm) are measured using an n&k Analyzer manufactured by n&k Technology, Inc.

The optical properties of the films for 193nm radiation were as follows:

Film Polymer	$n$	$K$
Polymer A	1.656	0.006
Polymer B	1.726	0.390
Polymer C	1.556	0.000
Polymers C & D (1:1 wt/wt)	1.689	0.205

## Example 4

## 20 Shelf life study

A formulation described in Example 2 using Polymer B was divided into two batches. One batch was stored at -20°C over period of one month and the other batch was stored at 40°C over period of one month. The reflectance spectra of two films from each batch formed by the method described in Example 3 are identical demonstrating the formulation has not aged.

## Example 5

## 193 nm Lithography and Etching the hardmask/antireflective layer

The hardmask layer was formed as described in Example 3 using the Polymer B. A layer of PAR 715 acrylic-based photoresist (sold by Sumitomo) was spin-coated over the cured hardmask layer to a thickness of about 250 nm. The photoresist was baked at 130°C for 60 seconds. The resist layer was then imaged using a 0.6 NA 193 nm Nikon Stepper with conventional and annular illumination using APSM reticle. After patternwise exposure, the resist was baked at 130°C for 60 seconds. The image was then developed using commercial developer (0.26M TMAH). The resulting pattern showed 113.75 and 122.5 nm equal lines and space patterns.

The pattern was then transferred into the hard mask layer by a 20 second fluorocarbon based etch using a TEL DRM tool. The etch selectivity between the photoresist and the hardmask exceeded 10:1, demonstrating that virtually no resist is lost during the hardmask open etch.

The etch selectivity of the oxide to hardmask (Polymer B) was determined on blanket films to be 2.5 :1 and 3.3:1 for the resist (PAR 715) to oxide, respectively, using a fluorocarbon based etch performed on a TEL DRM tool. The combined etch selectivities will give an overall etch selectivity of the pattern transfer from oxide to organic resist >20:1 which is superior to any known organic hardmasks.

Claims

What is claimed is:

- 1 1. A composition suitable for formation of a spin-on antireflective  
2 hardmask layer, said composition comprising:  
3 (a) an SiO-containing polymer having chromophore moieties, and  
4 transparent moieties,  
5 (b) a separate crosslinking component, and  
6 (c) an acid generator.
- 1 2. The composition of claim 1 wherein said transparent moieties are  
2 substantially free of unsaturated carbon-carbon bonds.
- 1 3. The composition of claim 1 wherein said chromophore moieties  
2 contain unsaturated carbon-carbon bonds.
- 1 4. The composition of claim 1 wherein said transparent moieties are  
2 selected from the group consisting of perfluoroalkyl and trifluoromethyl.
- 1 5. The composition of claim 1 wherein said SiO-containing polymer  
2 further comprises a plurality of reactive sites distributed along the  
3 polymer for reaction with the crosslinking component.
- 1 6. The composition of claim 1 wherein said chromophore moieties are  
2 selected from the group consisting of phenyl, chrysenes, pyrenes,  
3 fluoranthrenes, anthrones, benzophenones, thioxanthenes,  
4 anthracenes, and compounds containing carbon-carbon double bonds.

- 1     7.     A method of forming a patterned material feature on a substrate, said  
2            method comprising:
- 3            (a)     providing a material layer on a substrate,  
4            (b)     forming over said material layer, an antireflective hardmask  
5                   layer from the spin-on antireflective hardmask composition of  
6                   claim 1,  
7            (c)     forming a radiation-sensitive imaging layer over said hardmask  
8                   layer,  
9            (d)     patternwise exposing said imaging layer to radiation thereby  
10                  creating a pattern of radiation-exposed regions in said imaging  
11                  layer,  
12            (e)     selectively removing portions of said imaging layer and  
13                   hardmask layer to expose portions of said material layer, and  
14            (f)     etching said exposed portions of said material layer, thereby  
15                  forming said patterned material feature.
- 1     8.     The method of claim 7 wherein said radiation is selected from the  
2            group consisting of (a) ultraviolet radiation having a wavelength less  
3            than 200 nm, and (b) electron beam radiation.
- 1     9.     The method of claim 7 wherein said material layer is selected from the  
2            group consisting of dielectric, metals, and semiconductors.
- 1     10.    The method of claim 7 wherein said hardmask layer has a thickness of  
2            about 0.02 - 5  $\mu\text{m}$ .

# INTERNATIONAL SEARCH REPORT

International application No.

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## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G03F 7/00, 7/004, 7/09, 7/26  
US CL : 430/9, 270.1, 271.1, 272.2, 322, 510, 512, 950

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 430/9, 270.1, 271.1, 272.2, 322, 510, 512, 950

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
Please See Continuation Sheet

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P	US 6,503,689 B2 (ZAMPINI et al.) 07 January 2003 (07.01.2003), column 5, line 20-column 6, line 67, column 8, lines 18-28, column 9, line 41-column 10, line 67, column 13, lines 50-67, column 17, lines 8-30.	1-5, 7, 8, 10-19
Y, P		6, 9
Y, P	US 6,410,209 B1 (ADAMS et al.) 25 June 2002 (25.06.2002), column 7, lines 14-51.	6, 9
A, P	US 6,420,088 B1 (ANGELOPOULOS et al.) 16 July 2002 (16.07.2002), column 2, lines 8-60.	1-19
A, P	US 2002/0195419 A1 (PAVELCHEK) 26 December 2002 (26.12.2002), [0021], [0028], [0029], [0031].	1-19
A	US 6,268,457 B1 (KENNEDY et al.) 31 July 2001 (31.07.2001), entire document.	1-19

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 July 2003 (23.07.2003)

Date of mailing of the international search report

11 AUG 2003

Name and mailing address of the ISA/US

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# INTERNATIONAL SEARCH REPORT

PCT/US03/10590

## Continuation of B. FIELDS SEARCHED Item 3:

EAST

search terms: antireflective, ARC, polysiloxane, chromophore, transparent, crosslinker, acid generator